NAVIGATION FOR RENDEZVOUS AN I) ORBIT MISSIONS TO SMAI.L SOLAR-SYSTEM BODIES

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All previous spacecraft encounters with small solar-system bodies, such as asteroids and comets, have been flybys (e. g. Galileo's flybys of the asteroids Gaspra and Ida). Several future projects plan to build on the flyby experience and progress to the next level with rendezvous and orbit missions to small bodies. T 'his presents several new issues and challenges for navigation which have never been considered before. T 'his paper addresses these challenges by characterizing the different phases of a small body rendezvous and by describing the navigation requirements and goals of each phase.

1 'rior to the encounter with the small bod y, improvements to its ephemeris and initial estimates of its physical parameters, e.g. size, shape, mass, rotation rate, rotation pole, and possibly outgassing, are made as accurately as ground-based measurements allow. This characterization can take place over years.

This paper does not specifically discuss the cruise of the spacecraft from launch to the small body, since it is essentially like any other spacecraft traveling through interplanetary space. As a result, the next phase begins at optical acquisition of the body by the spacecraft and continues until delivery of the probe to some nominal distance (thousands of kilometers) from the body. The highlight of this phase is a series of maneuvers, targeted to the body, which virtually eliminate the spacecraft's hyperbolic excess velocity, allowing the spacecraft to approach the body at a reduced speed.

As the spacecraft approaches the body, an optical information base is begun. From this, a better estimate of the body's size, shape, attitude dynamics and mass can be developed. This leads to a preliminary gravitational model. If the body is a comet, then the major jets on the comet surface are located and preliminary estimates of the outgassing field must be made. The spacecraft then enters into an initial orbit about the body, normally at a greater altitude than the primary mission phase. The gravitational harmonics and mass of the body arc estimated, ant] if the body is a comet, the outgassing field is also estimated, This is a crucial checkout period where the mission plans ant] control algorithms are evaluated in the actual environment at the small body.

After accomplishing the goals of the previous phases, the mission phase begins. This phase consists of an extended period of orbits about the body, and may also include the delivery of a probe to the surface of the body. The small size and mass of the body, as well as its irregular shape, will subject the spacecraft to large perturbations from [gravitational harmonics, solar pressure, and non-gravitational effects. These effects become more significant when orbiting a small body, compared to a classical planetary orbiter. The perturbations and their effect on the orbit are estimated. If the perturbations are too large, or the requirements for controlling the orbit are too stringent, some degree of autonomous navigation may be necessary.

For the purpose of this study, the above rendezvous and orbit scenario has been divided into the following five phases:

1. Pre-encounter characterization
2. Encounter and Rendezvous phase
3. Initial Characterization phase
4. Initial Orbit phase
5. Mission phase

This paper will identify the most important issues in each of the above phases, discuss ways of overcoming the challenges that accompany these issues, and provide a methodology with which to approach navigation for small body missions.